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NEUTRINO TARGET-DETECTOR WITH TRIGGERED BUBBLE CHAMBER MODULES

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ABSTRACT

Large bubble chambers on the one hand, and large electronic target-detector systems on the other hand, both have major limitations on the information they provide for individual neutrino interactions at high energies. The use of hybrid muon-identifying electronic chambers downstream of large bubble chambers is one method for attempting a more complete event analysis. Here we consider an alternate approach in which bubble chamber modules are introduced as auxiliary visual targets in large electronic detector systems.

CONCEPTUAL DESIGN

The basic features of the present approach are illustrated in Figure 1. This depicts four bubble chamber modules in a large electronic target-detector. Conceptually, the configuration in Figure 1 can be thought of as a sliced-up Gargamelle bubble chamber interleaved as auxiliary components in a modular system such as that described by Benvenuti et al[1] for an augmented Experiment 1A detector at Fermilab. The purpose of the bubble chambers is primarily for high resolution observations on particles produced directly at neutrino interaction vertices. Quantitative data on hadronic and muonic energy components of such interactions would be chiefly provided by the electronic systems (liquid scintillators, wide gap chambers, drift chambers, etc.) in the same way as for interactions occurring in the non-visible portions of the target-detector.

NEUTRINO REACTIONS AND EVENT RATES

Estimates of triggered bubble chamber event rates can be made from the expected rate of high energy neutrino interactions for the augmented E1A detector. Tables I to III of reference (1) suggest that with 400 GeV protons targetting on a double horn, one can expect over 300 triggered neutrino interactions/metric ton/10^{17} protons.

The anticipated reactions and rates for a three ton triggered bubble chamber and ~10^{17} protons/day Fermilab exposure can be estimated for the above condition to be approximately 1000 neutrino (or about 270 antineutrino) interaction photographs per day with the following distributions:

Reactions	Triggered Pictures/Day/3 Ton Chamber
$\nu_\mu + N \rightarrow \mu^- + \text{hadrons}$	~900
$\nu_\mu + N \rightarrow \nu_\mu + \text{hadrons}$	~90
$\nu_e + N \rightarrow e^- + \text{hadrons}$	~10
$\nu_\mu + e^- \rightarrow \nu_\mu + e^-$	~0.1
or	
$\bar{\nu}_\mu + N \rightarrow \mu^+ + \text{hadrons}$	~200
$\bar{\nu}_\mu + N \rightarrow \bar{\nu}_\mu + \text{hadrons}$	~65
$\bar{\nu}_e + N \rightarrow e^+ + \text{hadrons}$	~1
$\bar{\nu}_\mu + e^- \rightarrow \bar{\nu}_\mu + e^-$	~0.1

BUBBLE CHAMBER PARAMETERS

In addition to very good optical resolution and a reasonably large interacting mass, the bubble chamber design for this application would emphasize economy and simplicity of operation as compared to conventional bubble chambers. The following assumptions and input parameters are aimed at accomplishing these design features:

1. Plastic scintillators are installed inside the bubble chamber, lining the beam entrance and exit walls, for triggering the flash tubes on desired interactions, as well as triggering the main calorimeter-spectrometer systems.
2. No magnetic field is provided.
3. Only freon is considered as the working fluid.
4. The chamber is constructed inexpensively of thick steel, with minimal shop work.
5. All the expansion system components are assembled on a top plate, which is removable.
6. Compressed nitrogen (or air) is used with clamped rubber membranes for the expansion system.
7. With Scotchlite illumination, fisheye optics and ~90° stereo, only two cameras are used per bubble chamber.
8. For an interacting mass of ~3 metric tons of heavy freon (CF_3Br with density $\rho \sim 1.5$ gm/cm^3) the required

liquid volume is ~2000 liters. This is one-sixth the Gargamelle volume, or one-fifteenth the volume of the Fermilab 15-foot chamber.

9. A long shallow bubble chamber configuration simplifies the expansion system, while a short and deep chamber is best matched to the liquid scintillator and other electronic detector components. A compromise configuration for a ~2000 liter chamber module could have lateral dimension of 1.5 to 2 meters and a depth of ~1 meter, representing ~2 collision lengths and ~10 radiation lengths for event analysis. For photographic purposes such a compromise configuration also appears desirable.

EVENT ANALYSIS

The electronic detectors in Figure 1 are especially designed[1] to provide good spectrometer analysis of secondary muons and calorimeter analysis of energetic forward hadrons. For these particles the triggered bubble chamber photographs can provide additional and corroborating information, such as detailed angular distributions and multiplicities. Where the bubble chamber pictures are expected to be especially useful, however, is in the following areas:

a. The neutral hadron (π°) component is expected to stand out strikingly for both muonic and muon-less interactions. Scan table estimates can also be obtained of gamma ray energies, directions and multiplicities, based on the electromagnetic cascades developed in CF_3Br with its radiation length of only 11 cm.

b. Electrons from neutrino interactions, with particular emphasis on the theoretically important pure leptonic reactions $\nu_\mu(\bar{\nu}_\mu)+e^- \to \nu_\mu(\bar{\nu}_\mu)+e^-$, would also stand out. Good optical resolution and short radiation length are important here, as witness the three events of this type found so far with the Gargamelle chamber.

c. Moderately energetic, slow and stopping hadrons should frequently be identifiable from ionization, scattering, range, decays and interactions.

d. Strange particle production in neutrino interactions would be a major topic of study.

e. Rare phenomena, such as multi-muon production, anamolous strange particles, charmed particle candidates, heavy lepton candidates, could be examined in full detail.

f. Search for new and hitherto unexplored neutrino-induced phenomena would be the most exciting aspect of physics research with this unique and powerful combination of bubble chamber and electronic detector techniques.

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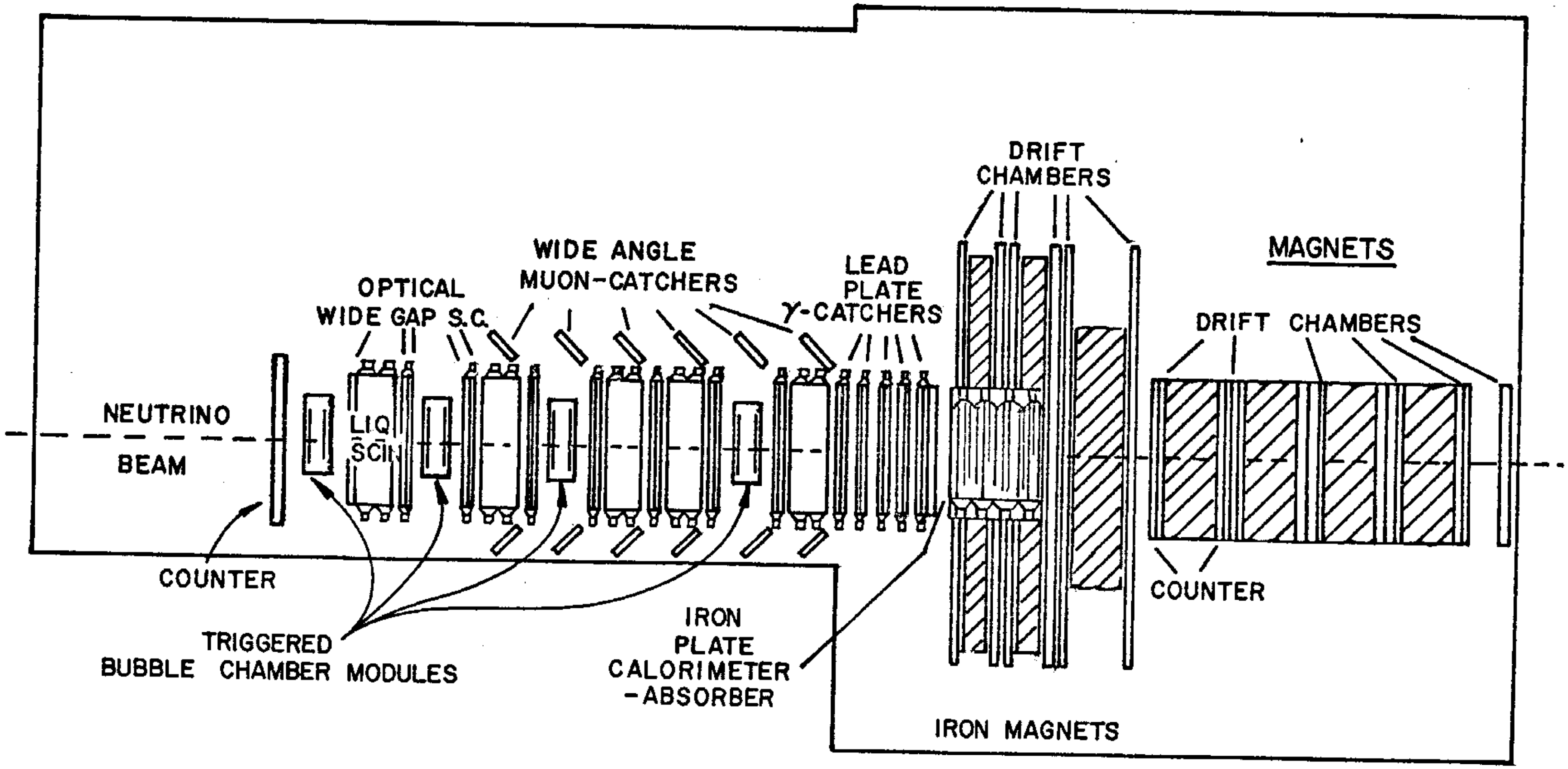
REFERENCE

(1) A.Benvenuti et al. Further Study of High Energy Neutrino Interactions at Fermilab, Harvard-Pennsylvania-Wisconsin-Fermilab collaboration. 5/31/74



NEUTRINO
BEAM
COUNTER
OPTICAL
WIDE GAP S.C.
LIQ
SCIN
WIDE ANGLE
MUON-CATCHERS
LEAD
PLATE
γ-CATCHERS
TRIGGERED
BUBBLE CHAMBER MODULES
IRON
PLATE
CALORIMETER
-ABSORBER
DRIFT
CHAMBERS
IRON MAGNETS
MAGNETS
DRIFT CHAMBERS
COUNTER

FIG. 1